NEW TECHNIQUES FOR WELDER CERTIFICATION

by

JAMES RICHARD RUBERSON

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INTRODUCTION

The use of electric welding in fabrication of bridges and buildings has brought about a need for welder certification. Inasmuch as the welding process is gaining in popularity for fabrication purposes the tests of welders to insure sound welds is a necessary requirement.

The purpose of this investigation was to study the possibility of devising a test which would insure that the welder being tested could produce sound welds while at the same time lower the cost of certifying the individual welder.

REVIEW OF LITERATURE

A thorough search of the library and other facilities for welder certification tests revealed that there was only one standard certification test listed. This test known as Standard Qualification Procedure was prepared and adopted by the American Welding Society in July of 1941 (2).

The Standard Qualification Procedure contains a complete breakdown of all phases of the welder certification test.

The American Welding Society Standard
Qualification Procedure

Part I - Procedure Qualifications.

. . .

102. Types of Tests and Purposes

The types of tests outlined below are to determine the tensile strength, ductility, and degree of soundness of welded joints made under a given Procedure Specification. The tests are as follows:

(a) For Groove Welds

(1) Reduced-Section Tension Test (for Tensile Strength)
(2) Free-Bend Test (for Ductility)
(3) Root-Bend Test (for Soundness)
(4) Face-Bend Test (for Soundness)
(5) Side-Bend Test (for Soundness)

(b) ...

103. Base Material and Its Preparation

The base material and its preparation for welding shall comply with the Procedure Specification. For all types of welded joints the length of the weld and the dimensions of the base material shall be such as to provide sufficient material for the test specimens called for hereinafter.

104. Position of Test Welds

All welds that will be encountered in actual construction, except groove welds in pipe, shall be classified as being (1) Flat, (2) Horizontal, (3) Vertical, or (4) Overhead in accordance with the definitions given in Fig. 1. Each procedure shall be tested in the manner stated below for each position for which it is to be qualified.

(a) Groove Welds in Plate

In making the tests to qualify groove welds in plate, the test plates shall be welded in the following positions:

(1) Flat Position - The test plates shall be placed in an approximately horizontal plane and the weld metal deposited from the upper side.
(2) Horizontal Position - The test plates shall be placed in an approximately vertical plane with the welding groove approximately horizontal.
(3) Vertical Position - The test plates shall be placed in an approximately vertical plane with the welding groove approximately vertical.
(4) Overhead Position - The test plates shall be placed in an approximately horizontal plane and the weld metal deposited from the under side.

(b) ...

105. Number of Test Welds Required

(a) Groove Welds in Plate or Pipe

For groove welds in material up to and including 3/4 in. thick, one test weld shall be made in material 3/8 in. thick for each procedure and position to be used in construction, except that if the construction involves welding of material over 3/4 in thick, a test weld shall be made in material of the maximum thickness to be used in construction for each procedure and position, but which need not exceed 1 in. If a test is made in the maximum or 1 in. thickness, no test need be made in the 3/8 in. thickness...

107. Test Specimens - Number, Type, and Preparation

(a) Groove Welds

For groove welds in plate the method of preparing the specimens shall be in accordance with the figures referred to in Table 1, and the number of tests required shall be as given in the table...

Table 1. Procedure qualification tests for groove welds in plate.

Maximum Thickness to be Welded in Construction	Test Plate Thickness	Number and Type of Tests Required			
		Reduced-Section Tension	Free-Bend	Root-Bend	Side-Bend
Up to and including 3/4 in.	3/8	2	2	2	-
Over 3/4 in.	Maximum, but need not exceed 1 in.	2	2	-	-

(b) ...

108. Method of Testing Specimens

...

(c) Root-, Face-, Side-Bend, and Fillet-Weld-Soundness Specimens

Each specimen shall be bent in a jig having the contour shown in Plate I, Fig. 1, and otherwise substantially in accordance with that figure. Any convenient means may be used for moving the male member with relation to the female member.

The specimen shall be placed on the female member of the jig with the weld at midspan. Face-bend specimens shall be placed with the face of the weld directed toward the gap; root-bend and fillet-weld-soundness specimens shall be placed with the root of the weld directed toward the gap; side-bend specimens shall be placed with that side showing the greater defects, if any, directed toward the gap. The two members of the jig shall be forced together until the curvature of the specimen is such that a 1/ 32 in. diameter wire cannot be passed between the curved portion of the male member and the specimen. The specimen shall then be removed from the jig.

...

109. Test Results Required

The requirements for the test results shall be as follows:

...

(c) Root-, Face-, Side-Bend, and Fillet-Weld-Soundness Tests

The convex surface of the specimen shall be examined for the appearance of cracks or other open defects. Any specimen in which a crack or other open defect is present after the bending, exceeding 1/8 in. measured in any direction, shall be considered as having failed. Cracks occurring on the corners of the specimen during testing shall not be considered...

Part II - Operator Qualification.

...

202. Types of Tests Required

The qualification tests described herein are specially devised tests to determine the operator's ability to produce sound welds, and may or may not conform in every detail to the requirements of the Procedure Specification. It is not intended that the practices required in the qualification tests shall be used as a guide for welding during actual construction. The latter shall be performed in accordance with the requirements of the procedure specification.

The tests used for operator qualification are as follows:

(a) For Groove Welds

(1) Root-Bend Test
(2) Face-Bend Test
(3) Side-Bend Test

...

203. Base Material and Its Preparation

(a) The base material shall comply with the specification for one of the materials listed in the Procedure Specification. (In this case A 7 Steel for bridges and buildings). For all types of welded joints the length of the welds and the dimensions of the base material shall be such as to provide sufficient material for the test specimens called for hereinafter.

(b) For groove welds in plate or pipe where the thickness of the material for the tests as specified in Article 205 (a) is 3/8 in., the requirements needed to be met for a single V-groove butt joint for the preparation of the base material for welding are 3/8 in. thick, bevel 30° maximum, separation at root 3/16 in. maximum.

...

204. Position of Test Welds

(a) Groove Welds

For the purpose of determining the ability of an operator to make groove welds in various positions in plate or pipe the following positions for tests are required.

Test Position 1 G

Plates placed in an approximately horizontal plane and the weld metal deposited from the upper side,... This test made either in plate or pipe will qualify the operator for flat position welds in plate...

Test Position 2 G

Plates placed in an approximately vertical plane with the welding groove in an approximately horizontal plane,... This test made either in plate or pipe will qualify the operator for flat and horizontal welds in plate and pipe...

Test Position 3 G

Plates placed in an approximately vertical plane with the welding groove approximately vertical. This test will qualify the operator for flat and vertical welds in plate...

Test Position 4 G

Plates placed in an approximately horizontal plane and the

EXPLANATION OF PLATE I

Fig. 1. Guided Bend Test Jig.
Fig. 2. Sample specifications for bending.

PLATE I

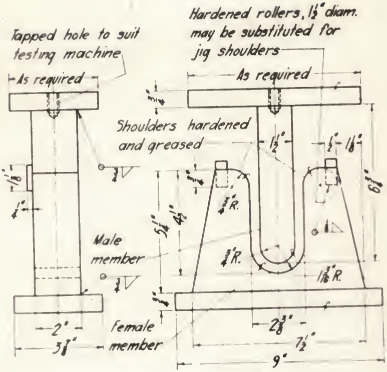
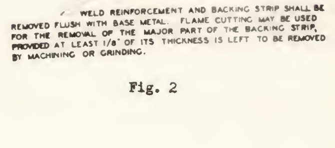

Tapped hole to suit testing machine
As required
Hardened rollers, 1½" diam. may be substituted for jig shoulders
As required
¾"
Shoulders hardened and greased
1½"
½"
1⅛"
1/8"
1/4"
¾
¾"
5¼"
4½"
6¾"
¾" R.
Male member
¾" R.
1 3/16" R.
¾
¾"
Female member
2"
3⅞"
2⅜"
7½"
9"

Fig. 1



WELD REINFORCEMENT AND BACKING STRIP SHALL BE REMOVED FLUSH WITH BASE METAL. FLAME CUTTING MAY BE USED FOR THE REMOVAL OF THE MAJOR PART OF THE BACKING STRIP, PROVIDED AT LEAST 1/8" OF ITS THICKNESS IS LEFT TO BE REMOVED BY MACHINING OR GRINDING.

Fig. 2

weld metal deposited from the under side. This test will qualify the operator for flat, and overhead welds in plate and for pipe in the horizontal rolled position.

...

If a welding operator is tested in Position 2 G he need not be tested in Position 1 G. If a welding operator is tested in Position 3 G he need not be tested in Position 1 G. If a welding operator is tested in Position 4 G he need not be tested in Position 1 G...

...

207. Test Specimens - Number, Type, and Preparation

(a) Groove Welds

For groove welds in plate the method of preparing the specimens and the number of tests required shall be as follows: Thickness of material for test weld 3/8 in., 1 root-bend, and 1 face-bend...

208. Method of Testing Specimens

(a) Root-, Face-, Side-Bend, and Fillet-Weld-Soundness Specimens

Each specimen shall be bent in a jig substantially in accordance with Fig. 1. Any convenient means may be used for moving the male member with relation to the female member.

The specimen shall be placed on the female member of the jig with the weld at midspan. Face-bend specimens shall be placed with the face of the weld directed toward the gap; root-bend and fillet-weld-soundness specimens shall be placed with the root of the weld directed toward the gap; side-bend specimens shall be placed with that side showing the greater defects, if any, directed toward the gap. The two members of the jig shall be forced together until the curvature of the specimen is such that a 1/32 in. diameter wire cannot be passed between the curved portion of the male member and the specimen. The specimen shall then be removed from the jig.

209. Test Results Required

(a) Root-, Face-, Side-Bend, and Fillet-Weld-Soundness Tests

The convex surface of the specimen shall be examined for the appearance of cracks or other open defects. Any specimen in which a crack or other open defect is present after the

> bending, exceeding 1/8 in. measured in any direction, shall be considered as having failed. Cracks occurring on the corners of the specimen during testing shall not be considered. (2) p. 6 - 18.

The Kansas State Highway Department does not use the A. W. S. Standard Qualification Procedure, but it has drawn up the State Highway Commission of Kansas, Supplemental Welding Specification, Supplementing Standard Specification 48.34, Edition of 1945. The procedure to be followed in qualifying both electric welding electrodes and base metals used are the same as the A. W. S. Standard Qualification Procedure.

There is a difference between the Kansas State Highway Commission requirements for certifying operators and the A. W. S. requirements. This difference is in the greater number of tests required by Kansas and in the thickness of material on which the weld is to be made.

The State Highway Commission of Kansas
Supplemental Welding Specifications

The Procedure to be Followed in Qualifying Electric Welding Operators.

1.03 - Classification of Operators

The operator shall be classified as to the type and position of welding he is qualified to do. The classifications shall be designated as small letter f, h, v, or o, indicating the positions flat, horizontal, vertical, or overhead, respectively, and capital letter F, H, V, or O, indicating the position Flat, Horizontal, Vertical, or Overhead, respectively.

Small letter operators will likely be used for welding involving fillet welds only, or for welding of minor importance. Capital letter operators will likely be required for welding involving butt welds, or other welds of major importance, when so designated on the plans or requested by the Bureau of Public Roads. However, the requirement as to the classification that the welder must meet will be shown on the PLANS for the piece of work involved and will govern.

1.04 - General Information Concerning Tests

The qualification tests for the small letter operator shall include only the "Guided Bend Test" and for the capital letter operator shall include both the "Guided Bend Test" and the "Deposited Metal Test". These tests shall be made with an electrode chosen by the operator or his employer, and shall be prepared in all positions in which welding is to be done, as required by the Engineer or the Plans.

The "Guided Bend Test" and the "Deposited Metal Test" shall be divided into two parts, for each operator, in each position involved. The specimens in the first part (Tests 1a and 1b) shall be made under shop machined supervision (unattended by any State representative), cut, completely machined (at the expense of the operator or his employer), and submitted for testing. If these test specimens meet the requirements, a representative of the Kansas State Highway Commission will witness the preparation of the specimens for the second and final part (Tests 2a and 2b). These test specimens, after being cut out (at the expense of the operator or his employer), will be taken by the representative for machining (at the expense of the State) and testing.

Section 2.00 - Test 1a (Under Shop Supervision - Unattended by State Representative and State Testing)

2.01 - Preparation of Test Plates

The base metal used in making this test shall be taken from one plate insofar as possible. Unless otherwise instructed the metal shall conform to the A. S. T. M. Specifications for Bridge Steel, Serial Designation A 7 - 49R or as specified by the engineer.

Test specimens shall be made so that the welds are normal to the direction of rolling. This will tend to counteract any influence which might be caused by slight lamination of the plate.

The plates to be used in this test shall be made to conform to the dimensions as follows: length 9 in., width 7 in., thickness 1/2 in., having a nose of 1/16 in. and a maximum bevel of 30°. Two such plates will be required for each position in which the operator is qualifying. No back-up plate is allowed.

2.02 - The Guided Bend Test

Specimens shall be prepared for each position involved in subsequent work, except the flat position which may be omitted when the horizontal, vertical, or overhead positions are required.

The plates shall be securely tacked together before welding is started. The plates shall be welded together by the following procedure: for flat position there shall be four passes made with pass 1 and pass 2 being made from opposite sides of the plate; for horizontal, vertical, and overhead positions a total of seven passes shall be made with pass 1 and pass 2 being made from opposite sides.

The test plates shall be clamped down or otherwise supported to prevent warping. The specimens shall be allowed to become cool to the hand before the slag is removed from each pass and the subsequent passes deposited. The weld reinforcement shall be just sufficient to insure full cross-sectional area after machining. The specimens shall be cut from the welded plates by sawing or precision cutting with a gas torch, in the following manner; two pieces 1 1/2 in. wide shall be removed from each side, the remaining 4 in. strip shall be cut into two sections each 2 in. wide. They shall be marked for identification.

Test welds shall not be peened or heat-treated in any manner. Care should be exercised when cutting with a gas torch so as to not heat-treat the weld metal.

2.03 - Machining of the Guided Bend Test Specimens

A light cut shall be taken length-wise of the specimen on the "face" surface, care being taken to remove only enough weld metal to clean-up the "face" surface. The specimen shall then be machined to the required thickness from the "root" side. Both surfaces shall be smooth with all tool marks removed. The finished specimen shall be 12 in. by 1 1/2 in. by 0.350 in., with edges machined to a 1/16 in. radius to remove sharp edges.

A light cut shall be taken length-wise of the specimen on the "root" surface, care being taken to remove only enough weld metal to clean-up the "root" surface. The specimen shall then be machined to the required thickness from the "face" side. Both surfaces shall be smooth with all tool marks removed. The finished specimen shall be 12 in. by 1 1/2 in. by 0.350 in.

In both the "face" and "root" specimens the original width of 2 in. shall be machined to the finished width of 1 1/2 in. (3) p. 1 - 4.

The bending of the samples conforms exactly with the requirements of the A. W. S. Standard Qualification Procedure. The required results of the Bend Test are the same for both the Kansas State Highway Commission and the A. W. S. Standard Qualification Procedure with the exception that the Kansas State Highway Commission will not allow a crack over 3/16 in. long occurring on the corners of the specimen during testing to pass.

Both the A. W. S. Standard Qualification Procedure and the Kansas State Highway Commission require that the tests be run on A. S. T. M. A 7 Steel for Bridges and Buildings.

American Society for Testing Materials, Specifications

Process

The steel shall be made by either or both of the following processes: open-hearth or electric furnace. Acid-Bessemer steel shall not be used on bridges.

Chemical Composition

When subjected to the ladle and check analyses, respectively, required by the provisions of Specification A 6, the steel shall conform to the requirements as to chemical composition prescribed in Table 2 except for bar-size shapes or bars 1/2 in. and under in thickness.

Table 2. Chemical requirements.

	Ladle Analysis	Check Analysis
Phosphorus, max. per cent open-hearth or electric furnace		
Acid	0.06	0.075
Basic	0.04	0.05
Sulfur, max. per cent open-hearth or electric furnace	0.05	0.063
Copper, when copper steel is specified min. per cent	0.20	0.18

Tensile Properties

(a) The material as represented by the test specimens, except as specified in paragraph (b) of this section, shall conform to the requirements as to tensile properties prescribed in Table 3.

Table 3. Tensile requirements.

	Plates, Shapes, and Bar
Tensile Strength, psi	60,000 to 72,000
Yield point, min., psi	33,000
Elongation in 8 in., min. per cent	21
Elongation in 2 in., min. per cent	24

(b) Shapes less than 1 sq. in. in cross-section, and bars, other than flats, less than 1/2 in. in thickness or diameter need not be subjected to tension tests.

(c) For material under 5/16 in. in thickness or diameter a deduction from the percentage of elongation in 8 in. specified in the above table of 1.25 percent shall be made for each decrease of 1/32 in. of the specified thickness or diameter below 5/16 in.

(d) For material over 3/4 in. in thickness or diameter, a deduction from the percentage of elongation in 8 in. specified in the above table of 0.50 per cent shall be made for each increase of 1/8 in. of the specified thickness or diameter above 3/4 in. This deduction shall not exceed 3 per cent.

Bending Properties

The bend test specimen shall stand being bent cold through 180° without cracking on the outside of the bent portion to a ratio of 1/2 of the thickness of material in inches to the bend diameter of the specimen. (1) p. 358.

Parts of the published material were omitted from the quoted material because they pertain to various aspects of the tests which were of no interest in this thesis.

EXPERIMENTAL PROCEDURE

Survey

In order to determine how widely the A. W. S. Standard Qualification Procedure was used, and to gather some data on the cost per welder for certification in other states, a survey of all Highway Departments in the United States was made.

The following questions were asked. (1) Do you require that your welders on state buildings and bridges be certified? (2) Do you use the A. W. S. Standard Qualification Procedure for qualifying welders? (3) If the answer to No. 2 is no, what Standard of Qualification do you use? (4) What is the average cost for certifying a welder?

Methods of Reducing Cost

A Single Plate Positioned at a Compound Angle. The plate would be positioned so that the groove to be welded would be inclined at an angle of 15 degrees from the vertical and at the same time tilted toward the operator at an angle of 15 degrees. By using this double or compound angle it was felt that a weld made in this position, while not conforming with the positions as set forth by either the A. W. S. Standard Qualification Procedure (Plate 2) or the Kansas State Highway Commission, would give a true indication of the welders ability to produce sound welds in all positions. Providing this assumption could be substantiated by test results, then the cost could be reduced two-thirds on each certification, while still giving indications that the welder could produce sound welds in all positions.

A Thinner Test Plate. This solution would apply only to the State of Kansas. Since the Kansas State Highway Commission specified that the tests be made on material 1/2 inch thick, (3) p. 2, and the A. W. S. Standard Procedure specified material 3/8 inch thick, (2) p. 8, that results of tests performed on materials of both thicknesses would be compared.

The tests made on 1/2 inch material were to be machined in accordance with the Kansas Highway Commission Specifications, and those made on 3/8 inch material were to have the weld reinforcement ground off. Providing it was proven that the test welds made on 3/8 inch material and ground were as critical as those made on 1/2 inch material and machined, the cost of machining could be completely removed by making the tests on 3/8 inch plate and grinding off the excess weld reinforcement.

At the same time these tests were being made a test on the same thickness of material was to be made at the compound angle and the results were to be compared with those made at the standard positions.

X-Ray Examination. The welds in the test plates were to be examined by the use of X-Ray plates to determine the amount of slag and presence of any voids in the weld. It was thought that in at least some cases enough could be determined about the soundness of the weld by examination of the processed film to justify stopping the test at this point, thus cutting out the cost of cutting and machining the sample for bending.

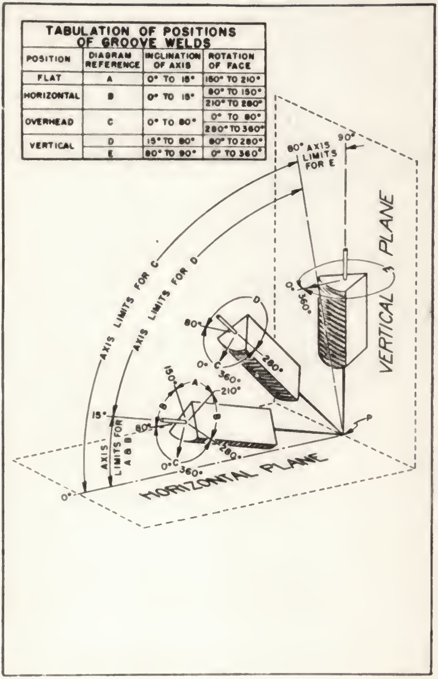
Materials and Equipment

Steel. The steel used for conducting these tests was A. S. T. M.

EXPLANATION OF PLATE II

Positions for Groove Welds in plate

PLATE II

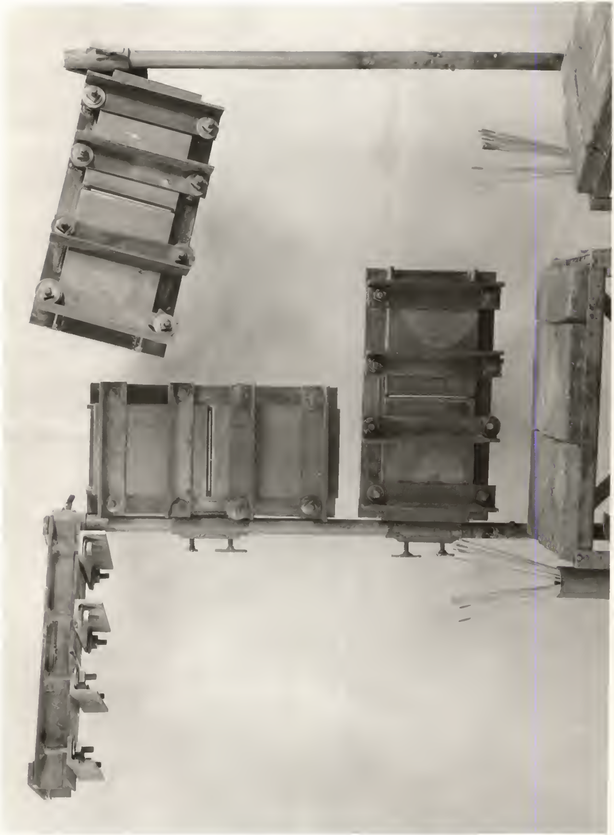


TABULATION OF POSITIONS OF GROOVE WELDS			
POSITION	DIAGRAM REFERENCE	INCLINATION OF AXIS	ROTATION OF FACE
FLAT	A	0° TO 15°	150° TO 210°
HORIZONTAL	B	0° TO 15°	80° TO 150°
			210° TO 280°
OVERHEAD	C	0° TO 80°	0° TO 80°
			280° TO 360°
VERTICAL	D	15° TO 80°	80° TO 280°
	E	80° TO 90°	0° TO 360°

EXPLANATION OF PLATE III

Welding jigs used in welding test samples

PLATE III



designation A 7 certified steel. See page 12 for chemical requirements and specifications.

Electrodes. The electrodes used were produced by two different companies. Both met the specification for A. W. S. and Kansas Highway Commission. These specifications called for Joint A. W. S., A. S. T. M., E6010, 5/32 D C Reverse heavy coated electrode. One rod was produced by the Hobart Welding Company and was designated Hobart No. 10. The other electrode used was produced by the National Cylinder Gas Corporation and was designated NCG type B. The Hobart No.10 was apparently an old rod and had picked up some moisture, because drying it in an electric furnace overnight at a temperature of 350 degrees seemed to produce less gas inclusions in the weld.

Welder. The welder used was a Hobart 180 ampere, direct current, motor-generator type machine.

Welding Jigs. The jigs used for positioning and to prevent warpage were made of 2 in. by 2 in. by 1/4 in. angle iron 18 inches in length, with two pieces of strap iron 2 in. by 1/4 in. welded perpendicular to the angle iron to hold them 7 inches apart. Four pieces of angle iron 2 in. by 2 in. by 1/4 in. were used to clamp the plates in the jig to prevent distortion while the actual welding was done. These pieces were held in place by 5/8 inch machine bolts (Plate III).

Each jig was held in position by welding a short piece of pipe, which had had the inside diameter machined to slightly over 1 1/2 inches so that it would fit over a 1 1/2 inch bar, to the jig (Plate III). The bar was attached to a welding table and was of sufficient height to allow the jigs to be placed so that the welding could be done in a comfortable position.

Shapers and Milling Machines. These machines were used in preparing the samples for bending. All of the plates were sliced into sections 1 1/2 inches wide on a Cincinnati Model N1-18 milling machine using a gang cutter (Plate IV). The 1/2 inch thick plates were then machined on a Gould and Eberhardt 18 inch shaper to the required 0.350 inches. Section 2.03 shows the specification.

Sample Bending Machine. All of the samples were bent on a jig meeting the requirements of both A. W. S. and Kansas Highway Commission Specifications (Plate I, Fig. 1). Two sets of samples were bent under the supervision of the State Highway Department Testing Laboratory. The balance of the samples were bent in the shop on a hydraulic press fitted with guided bend jigs (Plate V).

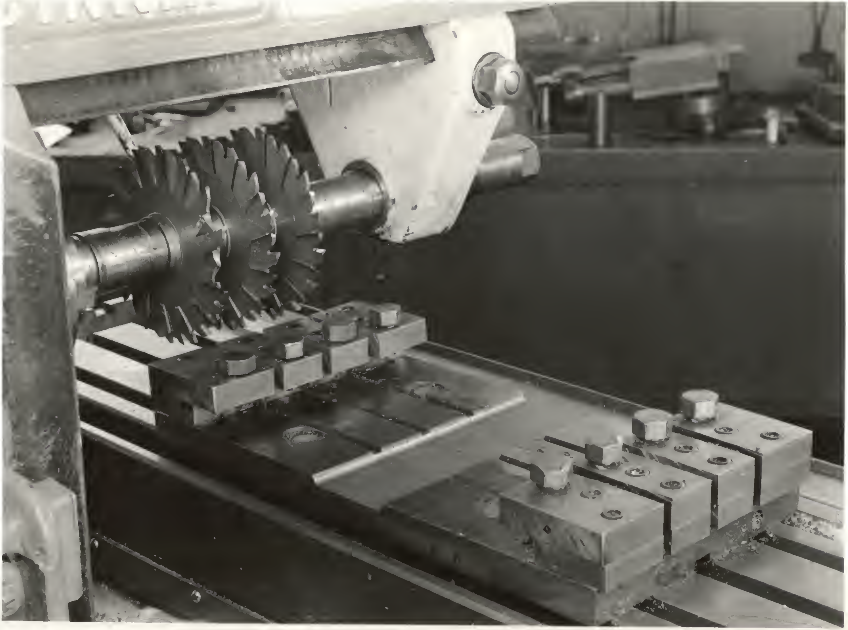
Welding Procedure

After the samples were cut to size, beveled, and the nose ground on the 1/2 inch material they were clamped in position in the welding jigs. The welding machine was allowed to run for approximately five minutes in order to obtain a true reading of the open circuit voltage. An open circuit voltage of 90 volts was recorded with a closed circuit voltage of 22 to 24 volts. The amperage was set for 105 amperes on the first two passes and increased to 115 amperes on the subsequent passes. Each pass was allowed to cool to a temperature at which the hand could be placed on the weld before removing the slag and proceeding with the next pass. A light

EXPLANATION OF PLATE IV

Machine and Jig setup used in cutting
samples to size for bending

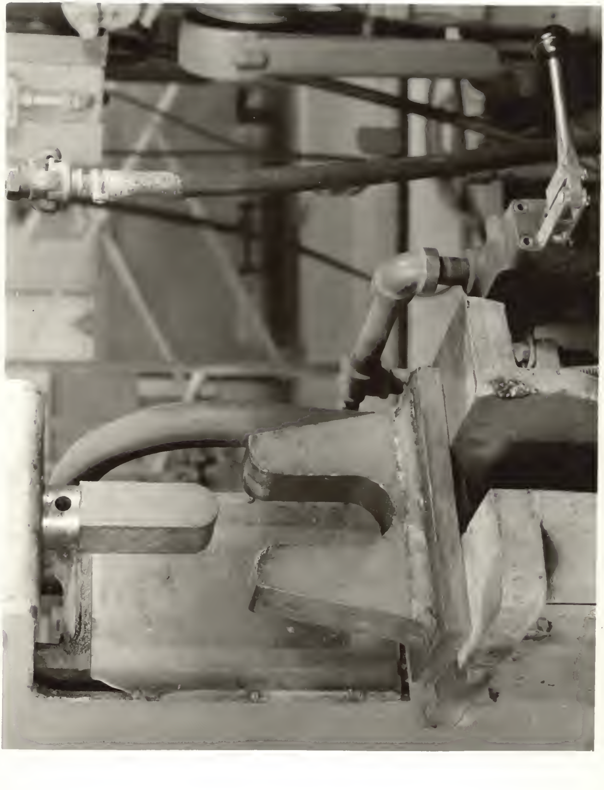
PLATE IV



EXPLANATION OF PLATE V

Sample Bending Jig and machine
as used in bending samples

PLATE V



chipping hammer and steel brush was used to remove the slag. By using a light chipping hammer very little if any peening was done to the surface of the weld.

Passes one and two were deposited from opposite sides of the plate in accordance with both A. W. S. and Kansas requirements. The final pass was a wash bead covering the entire weld and used as an annealing pass.

After the weld had sufficiently cooled the plates were removed and stamped with a number and position.

Sample Preparation for Bending

After welding the samples were prepared for testing by removing, by grinding, in the case of the 3/8 inch material, and by machining in the case of the 1/2 inch material, the excess weld reinforcement. After removing the excess weld reinforcement the 3/8 inch plates were ready to be cut into strips of the specified size (Plate I, Fig. 2).

In the case of the 1/2 inch material it was necessary to machine the plate to remove the mill scale before these plates were ready to be cut.

The plates were mounted in a jig and cut with a gang milling cutter on a Cincinnati Model Nl-18 milling machine. These samples were marked with the test number and the position in which the welding was done. Two samples were taken from each plate.

The samples cut from the 1/2 inch plate were then machined to a thickness of 0.350 inch as required by the Kansas Highway Commission. The sample being machined for the "root" bend having the excess metal removed from the "face" side, and the "face" bend sample having the excess metal removed from the "root" side.

Testing the Sample in a Guided Bend-Test Jig

After preparing the sample to meet the required specifications the samples were tested by bending them in a guided bend-test jig meeting the specifications set forth by both the A. W. S. Standard Qualification Procedure and the Kansas Highway Commission.

The shoulders of the jig were lubricated with Number 3 Axle Grease to reduce the galling effect. The samples were placed with the weld at mid-point of the female jig. For the "root" bend the sample was placed with the "face" side up, and for the "face" bend the sample was placed with the "root" side up. The two members of the jig were actuated by hydraulic pressure forcing them together and bending the sample to an angle of 180 degrees.

X-Ray Techniques

The samples were x-rayed several times. The first x-ray was made while the excess weld reinforcement was intact. A second plate was made after the removal of the weld reinforcement, and a third plate was made when the sample was ready to bend. These tests were made on a General Electric 250 Industrial X-Ray unit.

RESULTS

Survey

The replies to the survey of State Highway Departments in the United States were compiled and are presented in Table 4. The number of replies and the information contained in them exceeded the expectations of the writer when they were mailed. The results were tabulated and are shown in Table 5.

Table 4. Results of the survey of State Highway Departments.

	Per cent	Number
Questionaires returned	87.5	42
States requiring certification	76.2	31
States using A.W.S. Standard Procedure	71.4	30
States listing a cost figure	40.4	17
States listing cost as unknown	33.3	14
States leaving cost blank	26.2	11

From the results of the survey it was readily seen that the A. W. S. Standard Qualification Procedure was very widely used. Some of the states indicated that they did not conduct the testing but turned all of the testing over to private laboratories. It is very possible that these private laboratories use the A. W. S. Standard Qualification Procedure. If such were the case then the percentage would be even greater for the use of the A. W. S. Standard Qualification Procedure than was indicated by the survey.

The question of cost for certification was not expected to receive as many replies as were the other questions, and the results seemed to justify this conclusion.

The range of cost was from a low of $18.00 to a high of $260.00 with six states listing a cost of $100.00 or more. In regard to these figures, it was understood that the replies would give only an estimated cost which they did. Some replies did state, however, that this figure did not take into consideration the cost of supervision. Others stated that the cost listed was for materials only, and it did not include the cost of machining and bending.

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Table 5. Replies from State Highway Department survey.

State	Requires Certified Welders	Uses AWS Standard	Cost Average	Remarks
Alabama	yes	yes	unknown	
Arizona	yes	yes	$100.00	
Arkansas	yes	yes	unknown	
California	yes	yes	$100.00	
Colorado	no	no		
Connecticut	yes	yes	no	no cost to operator
Delaware	no	no		
Florida	yes	yes	unknown	
Georgia	yes	yes	$45.00	actual cost
Idaho	no	no		
Illinois	yes	yes	unknown	company pays cost
Indiana	no	no		
Iowa	yes	yes	$100.00	$12.50 per plate
Kansas	yes	yes	$100.00	
Kentucky	yes	yes	unknown	
Louisiana	yes	yes	unknown	
Maine	no reply			
Maryland	yes	yes	$50.00	
Massachusetts	yes	yes	$25.00	
Michigan	yes	yes	$20.00	
Minnesota	no reply			
Mississippi	no	no		
Missouri	yes	yes	$25.00	
Montana	no	no		
Nebraska	yes	yes	$50.00	
Nevada	no	no		
New Hampshire	no reply			
New Jersey	no reply			
New Mexico	no reply			
New York	no reply			
North Carolina	yes	yes	unknown	
North Dakota	yes	yes		
Ohio	yes	yes	$100.00	
Oklahoma	yes	yes	$52.50	actual cost
Oregon	yes	yes	unknown	
Pennsylvania	yes	yes	$125.00	
Rhode Island	yes	yes	unknown	
South Carolina	yes	yes	$50.00	
South Dakota	yes	yes	no test,	requires current card
Tennessee	no	no		
Texas	yes	yes	unknown	
Utah	no	yes	unknown	
Vermont	yes	yes	$260.00	average total cost
Virginia	no	no		
Washington	yes	yes	unknown	

Table 5. (concl.)

State	Requires Certified Welders	Uses AWS Standard	Cost average	Remarks
West Virginia	yes	yes	unknown	
Wisconsin	yes	no	unknown	Private testing lab.
Wyoming	yes	no	$5.00 per plate	Private testing lab.

Methods of Reducing Cost

A Single Plate Positioned at a Compound Angle. No conclusive results could be made from the results of this test. The tests were run during the course of two summers which may have been one reason for failing to get enough accurate tests to draw a definite conclusion. During the summer of 1954, a delay in receiving the steel allowed insufficient time for producing a series of tests. This would have shown more conclusive results. The tests made in the summer of 1955 were rushed in order to complete the research when the operator was out of practice and did not have time to regain his technique before welding the test plates.

The results of all tests made are tabulated and presented in Table 6. There seems to be a more definite correlation between the compound angle plates and those welded in the vertical position. This is not a definite conclusion and is probably brought about due to the similarity in techniques used in making the welds.

A Thinner Test Plate. The tests made using 3/8 inch material instead of 1/2 inch material were not conclusive, due to the reasons stated above. However, there seems to be enough evidence to show that the welds made on 3/8 inch material were as critical as those made on 1/2 inch material.

Table 6. Weld test results.

Material	Test No.	Root	Face	Reason for Failure	X-Ray	Remarks
1/2 in. Non-Certified	H1	ok	fail	slag	slag	practice test 1954 NCG rod
	M1	ok	ok		clear	
	01	fail	fail	slag, incomplete penetration	slag	
1/2 in. A 7 Certified	H2	ok	fail	slag	slag	shop bent 1954 NCG rod
	V2	ok	ok		clear	
	02	fail	ok	slag	slag	
1/2 in. A 7	HV03	ok	fail	slag	slag	shop bent 1954 NCG rod
	H3	ok	fail	slag	slag	
	V3	ok	ok		clear	
	03	ok	fail	slag	slag	
1/2 in. A 7	HV04	fail	fail	slag	slag	bent by SHD lab. 1954 NCG rod
	H4	ok	ok		clear	
	V4	ok	ok		clear	
	04	fail	fail	slag	slag	
3/8 in. A 7	HV05	fail	fail	slag	slag	bent by SHD lab. 1954
	H5	fail	ok	slag	slag	
	V5	fail	ok	slag	slag	
	05	ok	ok		clear	
1/2 in. A 7	HV06	fail	fail	slag too cold	slag	shop bent 1955. Hobart rod. Low amp.
	H6	fail	fail	slag	slag	
	V6	fail	fail	slag	slag	
	06	fail	ok	slag	slag	
3/8 in. A 7	HV07	fail	fail	slag	slag	shop bent 1955. Hobart rod. Low amp.
	H7	ok	fail	slag	slag	
	V7	fail	fail	slag	slag	
	07	ok	fail	slag	slag	
3/8 in. A 7	HV08	fail	fail	slag and gas	slag	shop bent NCG rod Low amp. 1955
	H8	ok	fail	slag and gas	slag	
	V8	ok	fail	slag and gas	slag	
	08	ok	fail	slag and gas	slag	
3/8 in.	HV09	ok	fail	incomplete anneal		NCG rod Normal anp.
	H9	fail	ok	gas pockets and slag		
	V9	ok	fail	slag and gas		
	09	ok	fail	slag and gas		

Table 6. (concl.)

Material	Test No.	Root	Face	Reason for Failure	X-Ray	Remarks
3/8 in.	HV010	fail	ok	slag		CC rod
	H10	ok	fail	slag and gas		Normal amp.
	V10	ok	fail	incomplete anneal		
	010	ok	fail	incomplete anneal		

Although this action was not a result of this research it does add support to the idea that 3/8 inch material would produce adequate test results. The Kansas Highway Commission Supplemental Welding Specifications, Qualifications of Welders, effective date April 1, 1954, has been revised and the test of welders are now being conducted on material of 3/8 inch thickness. (4) p. 3.

X-Ray Examination. The x-ray examination of the test welds and the results of the guided bend test show quite conclusively that a fairly accurate prediction can be made through x-ray examination. This is especially true in cases of welds having slag inclusions and voids. It should be noted, however, that the interpretation of the x-ray plate requires some skill and a great deal of practice in comparing the plate with the actual bend test. It was noted in some cases where the sample contained a void or slag inclusion which would apparently cause failure, that no failure occured. This was caused by the position of the void or slag inclusion. Where the defect was above the central axis of the sample being tested, the defect was under compression rather than tension, which is thought to be the reason for the weld to pass rather than to rupture and fail.

X-ray examination will not reveal all of the defects of a weld. It will not reveal that the weld was made at too high an amperage, or in other words, too much heat. A weld made with excess heat tends to become brittle and will not stand being bent through the required 180 degrees.

CONCLUSIONS

The American Welding Society Standard Qualification Procedure is the most widely used welder certification test in use today.

In the compound angle weld test there seemed to be a positive correlation between the compound angle test and the standard vertical test. The value of this test was not definitely proven, however, and a number of further tests should be made. More conclusive evidence concerning this test could be obtained by comparing the results of tests made by several welders.

The number of tests made on 3/8 inch material and 1/2 inch material were insufficient to base a conclusion. The evidence seems to point towards the proof that welds made on 3/8 inch are as critical as welds made on 1/2 inch material. This is further substantiated by the change made in the Kansas Highway Commission Supplemental Welding Specifications, effective April 1, 1954, from 1/2 inch material to 3/8 inch material, for welder certification tests.

X-ray examination revealed the presence of slag and voids, but it did not prove entirely accurate in predicting whether or not the weld would pass or fail.

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NEW TECHNIQUES FOR WELDER CERTIFICATION

by

JAMES RICHARD RUBERSON

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The purpose of this research was an attempt to devise a new technique or procedure by which the ability of a welder to produce sound welds could be determined at a reasonable cost.

The results of the survey of all Highway Departments in the United States indicated that the American Welding Society Standard Qualification Procedure was very widely used. The few States which replied to the questionaire with requirements of their own had altered the A. W. S. Standard Qualification Procedure somewhat, but the basic fundamentals were the same. There was no indication from the specifications sent by these states that these changes lowered the cost of certification.

Of the new techniques tried, the most conclusive evidence was obtained in the x-ray examination. Slag inclusions and voids could readily be seen upon examination. It should be pointed out that only an operator with much training and practice could tell definitely that a test would fail, in some instances, due to these inclusions. The cost of the equipment would not be warranted for the purpose of certifying welders only.

The comparison of results made on 3/8 inch material as compared with tests made on 1/2 inch material had a tendency to prove that the tests on 3/8 inch material were as critical as those made on 1/2 inch material. The limited number of test results obtained do not constitute ample evidence upon which to base positive proof. The change from 1/2 inch material to 3/8 inch material by the State of Kansas tends to strengthen the conclusion that a 3/8 inch plate test would produce desired results.

A comparison of the results of the single compound angle tests with those of the standard tests showed a positive correlation between the compound angle and the standard vertical test. This was probably due to the similarity of technique used in making both welds.

More research could be done on this problem. A more conclusive test of the compound angle test would be the comparison of the results of several similar tests made by a number of certifying welders.

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